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ACNS Advisory Committee on Nuclear Safety

CCSN Comité consultatif de la sûreté nucléaire

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# A REPORT ON THE PUBLIC PERCEPTION OF RISK

by the

Advisory Committee on Nuclear Safety

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An Advisory Committee of the Atomic Energy Control Board of Canada — Secretariat Ottawa Canada K1P 5S9

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ABSTRACT

Noting that the public's perception of risk is real whether or not it is based on what experts call scientific fact, the report examines psychological, socio-economic, informational, and cultural factors affecting risk perception. In the case of nuclear energy it is concluded that the public has little knowledge of the many measures taken to control risks.

RÉSUMÉ

Compte tenu du fait que la perception du risque chez le public est réelle, peu importe qu'elle soit basée ou non sur des données scientifiques aux yeux des spécialistes, le présent rapport examine le niveau de connaissance du public, ainsi que les facteurs psychologiques, socio-économiques et culturels qui touchent la perception du risque. Il conclut, dans le cas de l'énergie nucléaire, que le public connaît peu les nombreuses mesures qui sont prises pour contrôler les risques.

Ce document est aussi disponible en français.

## EXECUTIVE SUMMARY

## PUBLIC PERCEPTION OF RISK

A Report from the Advisory Committee on Nuclear Safety
to the Atomic Energy Control Board

### INTRODUCTION (p.1)

The role of the Atomic Energy Control Board (AECB) is to ensure that any use of atomic energy is made in a safe manner. Through its regulations and licensing process the AECB works to ensure that nuclear activities, in particular the design and operation of nuclear facilities, achieve an adequate level of safety. The level of safety considered acceptable by the AECB is based on international as well as national experience.

It is important that an understanding of this chosen level of safety be communicated to the Canadian public. There is a segment of the public that perceives the risk of nuclear energy as being too high, while some feel the rules are too restrictive. Although the public views are not ignored by the AECB they have played only an indirect role.

The public's perception of risk is real, whether or not it is based on what experts call scientific fact. There is therefore a need for the AECB to be aware in detail of the nature of the public's perception of risk.

This report has been prepared by the Advisory Committee on Nuclear Safety as a contribution to a better understanding of the factors involved in the perception of risk.

### Definitions (p.2)

"Risk" in this report is defined as "the existence of a threat to life and health".

"Risk perception" is the process whereby risks are subjectively, or intuitively, understood. The term is often used in relation to lay people's assessment of risk, but studies have shown that statisticians and scientists also estimate risks according to intuitive 'rules' when they are outside their area of expertise or familiarity.

"Public perception of risk" is a concept that is more useful to public policy in setting standards to regulate technology than it is to the design of the technical facilities. The main tool for estimating public perception is the social survey or opinion poll.

"Nuclear power generation" or "nuclear power production" is broadly defined in this report to include all parts of the fuel cycle.

## MAJOR FACTORS IN RISK PERCEPTION (p.3)

### Psychological factors (p.3)

Risk perception is a more complex function than expressed in the common equation of: risk = probability x consequence. Events arising from different causes differ in acceptability even if the outcomes are similar. The perception of risk appears to be more influenced by consequences than by the probability of their occurrence. Various studies indicate that when the consequences are serious the question of probability is ignored.

Risk perception research, however, has given more attention to the perception of probability. A typical example is a 1982 study conducted in Oregon, USA, where the subjects markedly underestimated the probability of frequent events and overestimated the probability of very infrequent ones, narrowing the overall range by a factor of 400.

There appear to be three intuitive "rules" which lead to systematic errors in perception, identified as: "representativeness", "availability" and "anchoring". Representativeness refers to the tendency to be overly influenced by superficial similarities. Availability is the dependence on memory to bring examples to mind. Anchoring is the action of selecting an initial value and then adjusting it, although the adjustments are usually insufficient.

The concept of cause is strong; a common reaction to news of an event is to attribute a cause to it (attribution theory). This leads to the notion that there is a purpose, and therefore a pattern, to events. For events arising from man-made products, like nuclear power, causality and blame are likely to be attributed to people and not accepted as "chance". Studies show that initial attributions of cause, once made, are very persistent despite later conflicting information.

Judgements and decisions related to risk are influenced by the individual's frame of reference. For example the public is aware that risk-benefit trade-offs have to be made. The issue, however, is more one of "who pays and who benefits?" The public view of nuclear power is likely to favour a reduction of the risks even if benefits must be sacrificed.

The perception of the degree of control over one's fate is important. Risks from voluntary activities appear to be accepted more readily than those from involuntary ones. The "acceptable" level of risk for nuclear power is low partially because the public sees nuclear power as involuntary; in which case public acceptance will be influenced as much by <u>how</u> decisions are made as by the decision itself.

### Socio-economic and demographic factors (p.10)

There is evidence of broad socio-economic and demographic differences in risk perception. The relationship is most consistent for the knowledge component of perception. For example, in the case of risks such as nuclear power and acid rain:

- men are more likely to be better informed than women;
- young adults are better informed than older people;
- those with higher levels of education are better informed.

Regional differences in Canada in risk perception are relatively minor. However, for nuclear power, Ontarians showed the least concern while British Columbians were most opposed to it.

Information factors (p.13)

It is important to distinguish between "knowledge" and "awareness". Awareness does not imply any degree of understanding or even minimal knowledge. In a 1980 study less than 10 percent of Canadians polled were knowledgeable about the use of nuclear energy to produce electricity yet over 80 percent were prepared to voice an opinion. Clearly the public does not feel that ignorance is a reason for not taking a stand.

Information may be direct, from personal experience, or indirect. For the latter, the mass media, especially television, can be very important. Because the media emphasizes dramatic stories and events it can exaggerate the intuitive biases of risk perception. Nevertheless, mass media are believed more than governmental agencies, possibly because trust in governments has been declining.

A climate of confidentiality seems to confirm that the nuclear industry has information it is unwilling to share. Simply opening the files, however, is of little use when complex technical issues are involved. The public needs competent advice from someone whom they trust.

A decade or so ago "risk assessment" was almost unknown to the public. In the past 10 to 15 years the public has become educated about risks as something they are exposed to in their everyday lives. In the case of major events which present a risk to the public, the perception is cumulative. After the 1979 Mississauga train derailment, evacuees had a higher expectation of a major nuclear accident.

Culture and risk perception (p.21)

Some researchers contend that hazards and risks are not perceived but chosen by a cultural process. Therefore cultural aspects are important factors in risk perception and risk acceptance.

Recently the proposition has been made that the approach to risks should be examined in two dimensions: risk acceptance/risk avoidance, and, risk absorption/risk rejection. With this approach five different cultural types, each with its own style of risk handling can be described, from the "zero risk" individual (risk avoidance and risk rejection) to the "life-is-like-a-lottery" person (risk acceptance and risk absorption). In this view, any group's attitude to risk should be understood as part of its strategy to cope best with the problems of life as the members of the group see them.

MODELS AND THEORIES OF RISK PERCEPTION (p.23)

General attitude theory in psychology can also be applied to risk perception. Attitude to risk is often an attribute considered when describing someone's personality. Studies show that there is little consistency in attitudes towards risk-taking; one can be daring in one context while timid in another.

Risk perception involves both cognition (information processing) and affect (emotion, feeling). As a consequence, it becomes difficult to predict, in the real world, how particular risks will be perceived. The distinction in risk perception between "natural" and "man-made" hazards is not clear. More important is the assignment of responsibility, with few events now being accepted as "acts of God".

Studies show that a single parameter, e.g. deaths per megawatt-hour, as used by some scientists for comparative risk studies, is unsatisfactory for the public who judge several dimensions of risk.

MEASUREMENT AND OBSERVATION OF RISK PERCEPTION (p.27)

Methods of accumulating data (p.27)

Data on risk perception have been obtained primarily through three methods: laboratory experiments, field studies, and social surveys. Each has limitations. Experiments are isolated from the real world and tend to focus on probability. Field studies usually have inadequate sampling and scope, and neglect the social dimension. Surveys or polls obtain opinions with little or no context.

Canadian data on nuclear issues (p.29)

No Canadian experimental studies are known and there have been very few field studies regarding public attitude towards nuclear power. There are, however, more Canadian survey data on public attitudes to nuclear power than for any other environmental or energy issue.

Nuclear power is not high in the public's opinion of important problems, being volunteered by only one percent of those polled. Nevertheless, many are concerned, with recent polls showing that, nationally, 38 per cent opposed nuclear power.

Scope of concern about nuclear power (p.35)

As well as the national concern associated with nuclear power plant accidents and with the disposal of waste products from the nuclear fuel cycle, there is concern over the ethical implications of exporting nuclear technology to countries perceived as being politically unstable.

SOCIAL COSTS OF NUCLEAR POWER GENERATION (p.36)

In addition to the direct economic costs of any hazard there are less easily quantified psychological, social and health costs, such as the loss of productivity through anxiety. It has been argued in the USA that the additional socio-psychological cost of cancer could exceed the direct economic cost by a factor of ten or more. The critical factor is not the actual risk but that which is perceived by the public.

PUBLIC INFLUENCE ON NUCLEAR POWER GENERATION (p.37)

Although the public perception of the risks of nuclear power has undoubtedly had some effect it is difficult to identify direct influences except in the expansion of public information activities. Whether or not these activities are changing public perception there is no doubt that the perception remains that not enough is being told.

EDUCATION (p.38)

There are great needs for education of the public in matters of risk. The public needs to gain an appreciation of real health risks and to understand the philosophy of allocating funds to achieve the greatest increase in safety per dollar spent. There is also a need for a more general concept of risk which includes the public perception as well as the scientific one.

CONCLUDING OBSERVATIONS (p.40)

(1) The general public has little knowledge of the AECB's identity and function. It is unaware, in general, of the extent of the measures taken to control the risks associated with the production of nuclear power.

(2) Many people are concerned that the use of nuclear power, and particularly its export, could lead to the widespread proliferation of nuclear weapons. At the same time few are aware of the international "safeguards" that are in place to detect the diversion of nuclear material from power stations to military use, nor is much known about the important role that Canada plays in this "safeguards" process.

(3) Public debate is an important element in making people aware of the technological aspects and safety of nuclear power production. The quality of this debate could be enhanced in the long run by active promotion of education in this area in cooperation with the provincial governments. More immediate benefits could be realized by promoting closer contacts between technically informed individuals and the press, teachers and special interest groups.

(4) Although the assessment of risk is important in determining the safety of nuclear power plants, the concept of risk as a mathematical expectation of loss fails to capture much of the meaning of "risk" to those who are exposed. It is therefore necessary to promote and support a dialogue between those who do risk analysis and those who study the way in which risk is perceived by the public.

(5) The skills for doing risk assessment of complex technical systems are not widely available outside governments and Crown corporations. The public's anxiety over the risks of nuclear power technology might be substantially relieved if institutions considered as independent could develop the capacity and provide relevant Canadian data for risk analysis. Active research support from the AECB to universities and private groups could be one way to accomplish this.

(6) Increased public support for the nuclear program may well depend on the success of the current transition from confidentiality to an open process of information exchange between industry, government and the public.

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# PUBLIC PERCEPTION OF RISK

## 1. INTRODUCTION

### 1.1 Background and purpose

The role of the Atomic Energy Control Board (AECB) is not to promote atomic energy but to regulate its use; that is, to ensure that any use of it is made in a safe manner. To do this the AECB has produced over many years a large number of rules and regulations governing all uses of atomic energy, and particularly the siting, design and operation of nuclear facilities. Before permitting construction or subsequent operation of a facility it assures itself that all safety requirements have been met. In so doing, the AECB believes that an adequate level of safety will be achieved. The AECB's role continues throughout the life of any facility it has licensed and, through a series of reporting procedures and inspections, it reassures itself that safe operation is maintained.

The level of safety considered acceptable by the AECB is based on international, as well as national experience and reflects international consensus. It has been determined over many years through discussions with users and by deliberations of both the AECB staff and by input from the AECB's advisory committees. The current position is reflected in a series of licensing guides and regulations that set forth radiation dose limits and system safety requirements.

Perhaps equally as important as the task of controlling the level of safety of the nuclear industry is the task of communicating an understanding of this level of safety to all its constituencies of which perhaps the most important is the Canadian public. There is a segment of the public that perceives the risk currently presented by the use of nuclear energy as being too great. Some of these people deem the risk to be too great no matter what level is set. On the other hand, there are others who feel that the regulations are too restrictive, leading to misallocation of resources and to a higher cost of electricity than necessary.

These public views have in the past played only an indirect role in influencing the AECB's decisions. In recent years, however, public views have been actively sought by the issuance of proposed regulations and licensing documents for comment before new positions are adopted.

Within the scientific community there is perhaps some notion that the public perception of the risk posed by nuclear facilities (and nuclear power plants in particular) is not valid because it is not based on sufficient knowledge of the scientific fields involved and of the complex engineering details in safety analysis documents. In any case, the influence of public opinion (even the outspoken opinion of anti-nuclear groups), while being widely publicized, has not had much direct effect on the regulations that govern the use of atomic energy in Canada.

There is, therefore, in the Committee's view, a need for the AECB to be aware of the nature of the public's perception of risk. This perception is real whether it is based on emotion or on what experts call scientific fact and is relevant to the AECB's exercise of its important mandate.

As a contribution to a better understanding of the public perception of risk, the Advisory Committee on Nuclear Safety (ACNS) has prepared this background report on the topic.

### 1.2 Definitions

"Risk" in this report is defined as "the existence of a threat to life and health" (Fischhoff et al., 1981).

"Risk perception" is the process whereby risks are subjectively or intuitively understood. The term is often used in relation to lay people's assessment of risk but studies have shown that statisticians and scientists also estimate risks according to intuitive 'rules' when they are outside their area of expertise or familiarity (Tversky and Kahneman, 1974).

"Public perception of risk" is an aggregate of individual risk perception that is more relevant to public policy in setting standards to regulate technology than it is to the design of the technical facilities. Since the main tool for estimating public perception is the social survey or opinion poll, the measure is almost always the perception of a specified risk or class of risks (e.g. nuclear power, pesticides). Given the high cost of such surveys, there is usually a trade-off between the statistical validity and scale of the sample of the public, and the quality, depth or contextual validity of the question being posed.

"Nuclear power generation" or "nuclear power production" is defined broadly to include the risks from all parts of the fuel cycle, including mining, transportation, power cycle, waste storage, and diversion of fissile material to nuclear weapons as well as risks associated with reactors and heavy water production.

## 2. MAJOR FACTORS IN RISK PERCEPTION

### 2.1 Psychological factors

#### 2.1.1 Limitations in human information processing

The definition of risk as the mathematical expectation of consequences, with consequences usually measured in deaths, dollars lost or person-days of work lost, fails to capture some important aspects of risk. Risk perception is apparently a more complex function than expressed in the equation: risk = probability x consequence. Risk perception is believed to be influenced

less by the probability component than it is influenced by the nature of the anticipated, or feared, consequences (Hohenemser et al., 1983). In risk perception, deaths are not perceived as equivalent units of 'risk' because the time and way of death have different negative values for people. Similarly, the 'value of a life' depends on the individual concerned. Events arising from different causes, even with similar outcomes, differ in their acceptability to people. Thus definition of risk as the mathematical expectation of consequences fails to capture these important aspects of risk. In the view of this report, it is more useful to see the many elements that influence risk perception, not as the idiosyncracies of the uninformed, but as a challenge to the scientific community to produce more meaningful measures of risk that carry more meaning to the general public.

In risk perception research, particularly by psychologists, more attention has been given to the perception of probability than to the perception of consequences. This may be because perceived probabilities are more easily quantified, can be compared with mortality and morbidity statistics, and can be verified by stringent requirements of logical consistency.

An example of this approach is given in Figure 1, taken from Slovic, Fischhoff and Lichtenstein (1982). The relationship between lay people's perceived probability of death from 41 causes of death is compared with statistical estimates for the U.S.A. Each point in Figure 1 represents the average value for the subjective data obtained from 111 university students and 77 members of the League of Women Voters in Eugene, Oregon. Bars for selected points show the 25th and 75th percentiles of the range of perceptions observed. Despite the limitations of this study in experimental design and sample populations used, the main findings that the range of subjective probabilities are compressed compared to actual probabilities, are likely valid. Respondents were found to underestimate the proportion between the probabilities of the most and least frequent causes of death. In other words, the subjective estimates narrowed the range of this ratio of probabilities from about 1,000,000 to 2,500, i.e. by a factor of about 400. The survey did not include atomic energy as a cause of death.

The hazards whose probabilities are exaggerated by lay people tend to be characterized by high visibility, sensationalism and easy imaginability (e.g. botulism, tornado) while the incidence of common diseases like cancers, diabetes and heart disease was underestimated. Similar results have been reported for technological hazards (Slovic, Fischhoff and Lichtenstein, 1979).

There are several explanatory models for these and similar findings. The first is framed within decision making models of risky choices. The errors in subjective probabilities are ascribed to limitations in human information processing. Many well-designed experiments have shown that people (including scientists and statisticians away from their own subject matter) rely on a small number of short-cuts for estimating probabilities. Reliance on these intuitive rules often leads to systematic errors in judgment (Kahneman, Slovic and Tversky, 1982; Nisbett and Ross, 1980).

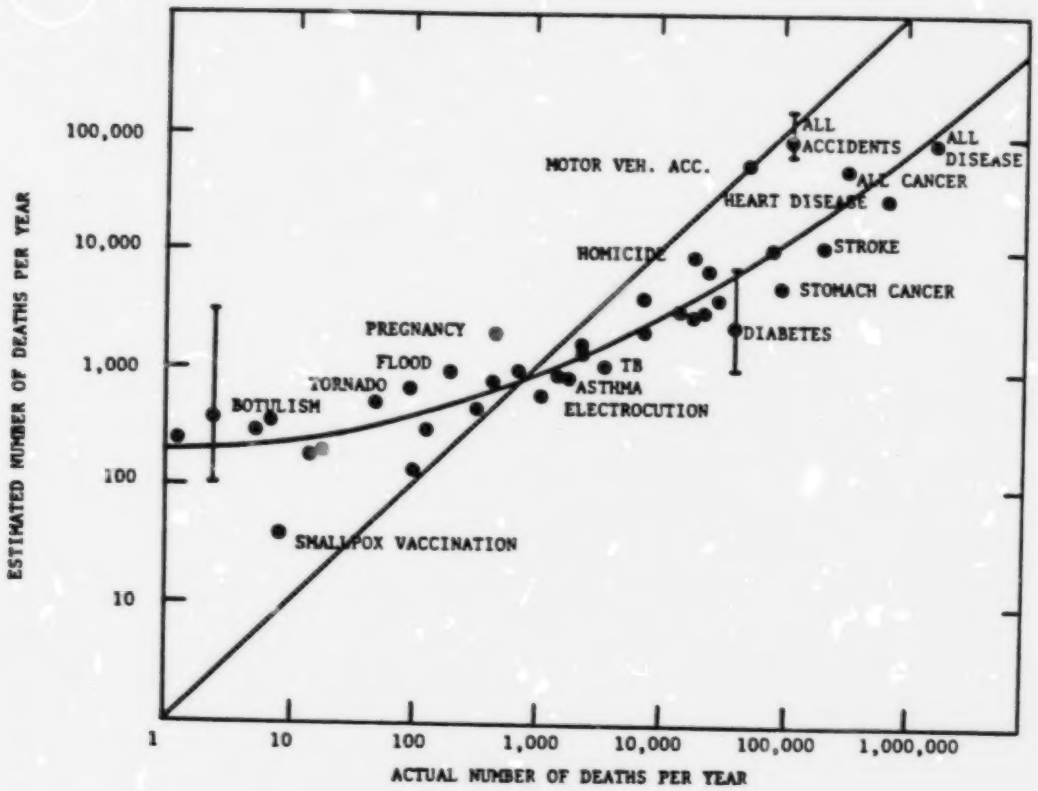



Figure 1 Relationship between perceived frequency and actual number of deaths per year for 41 causes of death in the U.S A. (Slovic, Fischhoff and Lichtenstein, 1982).

Three important rules, or "heuristics", are

(a) representativeness;
(b) availability; and
(c) anchoring.

Representativeness. People tend to evaluate probabilities without taking adequate account of base rate frequencies or relative sample sizes. They are overly influenced by superficial similarities and by stereotypes when estimating the probability that an observation X falls within class A or B. The heuristic also applies to judgments about chance events. The lay person's perception of randomness is that chance is a self-correcting process and that short random sequences will mirror longer sequences. The well known "gambler's fallacy", that after a long run of 'heads' a 'tail' is more probable is also based on intuitive reliance on the representativeness heuristic.

Availability in this context is the dependence on memory to bring examples of events to mind. If one can recall other similar events or observations, the subjective probability of event X is elevated. This heuristic introduces bias into perceived probability estimations because the memory, or availability of similar past events, is influenced by their salience (impact made on us, prominence or perceived relevance), the time elapsed since the last event, and their "imaginability".

It is this heuristic that seems to be operating to increase subjective probabilities of a traffic accident after we have passed an accident on the road. The availability bias could also account for the exaggeration of dramatic events like tornado and botulism as causes of death. Clearly the behaviour of the mass media in image-making and sensationalism can emphasize the role of the availability bias in perceptions of event frequency. There are few, if any, data relating this bias to decision-making behaviour.

Anchoring is also a decision heuristic that has been demonstrated in several experiments. When asked to estimate quantities or probabilities, people tend to select an initial value and then adjust it before reaching a final figure. Typically, the adjustments made (by mentally searching for more information and 'rationalising') are insufficient. The initial, more intuitive, value acts as an anchor. It is this initial value that is most influenced by the availability and representativeness bases. Thus anchoring compounds any error in probability judgment that has been made (Tversky and Kahneman, 1974).

The anchoring-and-adjustment process is also regarded as a factor in hyper-precision and overconfidence, to which both lay people and experts are prone. Studies of both automobile mechanics (Fischhoff, Slovic and Lichtenstein, 1977) and geotechnical engineers (Hynes and Vanmarcke, 1976) have shown that some experts can be very wrong even when they are confident of their estimates (Figure 2). Designs of engineered facilities usually

involve safety margins so generous that few designers ever have the misfortune to see their designs fail. As a result, a lifetime of experience may easily leave the expert with the belief that his estimates are correct, when they in fact may be either conservative, correct or unconservative.

When asked to estimate the risk of a given installation or activity scientists and engineers can rarely produce the necessary statistical or experimental data. Instead, they must extrapolate and generalize. To do so, they resort to "judgment", and are reduced to employing the same cognitive processes that lay persons use, with similar consequences (Hammond et al., 1984). It appears that professionals differ from lay people mainly in the amount and quality of information used, rather than in the skill with which they process information.

2.1.2 Concern with causes and consequences

The processing of information by humans, which has been discussed above in relation to subjective probabilities, goes some way to explain how differences arise between statistical probabilities and perceived risks. Another point of view is that the finer points of subjective probability are not very important to risk perception of nuclear power because public attitudes are primarily shaped by the perceived links between causes and effects, and by the nature of the consequences.

It has been argued that the effort of the nuclear industry to convince the public of the acceptability of nuclear power on the basis of its low probability as a cause of death is counterproductive, because public attention is not focussed on probabilities, however low, but on consequences, which conceivably could be high (Whyte, 1983).

It is this attention to the scale and quality of the consequences that makes people overestimate the deaths from jumbo jet crashes in comparison to many, smaller road traffic accidents, and overestimate deaths from botulism - a way of dying which is regarded as particularly horrible. Risk-benefit analyses and simple comparisons of the risk of death across different causes fail to capture peoples' repugnance to certain types of death. Some weighting procedure is clearly needed and some relevant data are available (Fischhoff et al., 1978b).

A common reaction to news of an event is to seek to attribute a cause to that event (attribution theory). It is apparently difficult for our intuition to accept that events can be 'uncaused' or, more accurately, be random.

The notion that there is purpose, and therefore pattern, to events is a very powerful one. For example, many studies of natural hazards, particularly hazards with a recurrence interval measured in years rather than in decades or longer, have found that lay people perceive a pattern where statistical records show none.

In the case of nuclear power the relevant question is to what extent are events at nuclear power stations (e.g., leaks) seen by lay people as a chance process, in which the people and places affected are 'selected' randomly. There are no studies designed to answer this question specifically. For man-made products like nuclear power, causality and blame are more likely to be attributed to

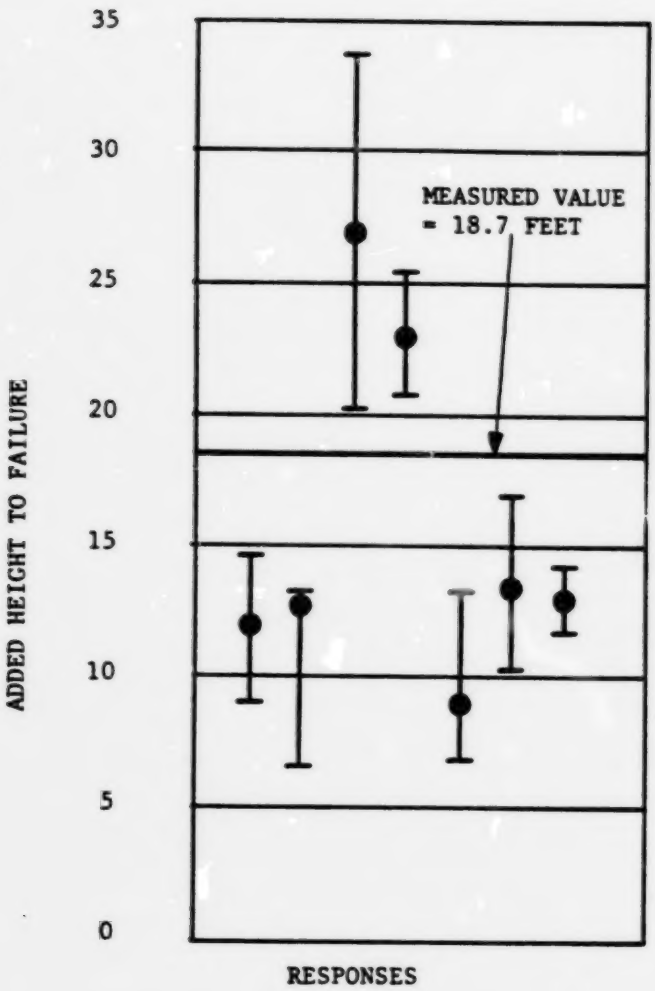



Figure 2 An example of overconfidence in expert judgement, as represented by the failure of error bars to contain the true value. The data represent estimates by seven "internationally known" geotechnical engineers of the height at which an embankment would fail. (Source: Hynes & Vanmarcke, 1976).

other people than to be accepted as 'chance'. Thus the perceived motivations, credibility and competence of those other people (or groups) are important variables in the perception of these risks.

Experimental studies have shown that initial attributions about cause and effect, and responsibility, once made, in general, are remarkably resistant in the face of later, conflicting information (Ross and Anderson, 1982).

Finally, reference should be made to the power of the worst-case scenario. The vision of a "Silent Spring" presented by Rachel Carson (1967) resulting from DDT in the environment, and the dread of a nuclear disaster are powerful influences on risk perception. When the scale of the conceivable consequences becomes very large, the perceived relevance of low probabilities diminishes almost to the vanishing point. The dread of the consequences will then dominate, and risk acceptability is reduced.

2.1.3 Decision framing.

It has been shown for decisions made under uncertainty that the reference frame in which the alternatives are viewed influences the decision reached.

There have been several experimental studies to examine the effects of decision-framing on choice (Kahneman, Slovic and Tversky, 1982). One study found that people reluctant to use automobile seat belts tended to frame their decision in terms of the probability of death per individual trip. This is very low (1 in every 3.5 million person-trips in the U.S.A.). However, persons who considered the risk over their whole lifetime (40,000 trips or a probability of being killed of 0.01) were more likely to believe in the efficacy of wearing seat belts. Studies like these have important implications for risk education.

Risk perception 'frames' can include or exclude the question of benefits just as can alternative frameworks for risk assessment. It is regarded as axiomatic that people will accept higher perceived risk if they are compensated with higher perceived benefit. In an early study of the mining industry in the U.S.A. Starr (1973) found that risks (measured in accidents per man per hour) were proportional to the cube of the benefits measured in hourly wage. Other studies, however, have not found a very consistent relationship between occupational risk and reward (e.g. Sinclair, 1972).

Formal cost-benefit and risk-benefit analyses have their parallels in intuitive decision-making. In both cases, the framing of the analysis is critical to the outcome. The public can understand a cost-benefit comparison and is aware (or can be made aware) that tradeoffs may have to be made. Therefore, the issue is not so much public inability to recognize the existence of tradeoffs as much as 'who pays and who benefits?' in their eyes.

Social surveys have probed the risk-benefit equation for the public on a number of environmental issues. Several U.S. surveys since the 1970's have asked the public about the tradeoff between economic growth and environmental protection. In polls conducted in 1975 and 1978 it was found that about 60% of the U.S. public preferred higher prices and a cleaner environment to lower prices and more air and water pollution (Harris Poll, 1975, 1978). These findings have been replicated in several other surveys. A survey in October 1979 found that 52% of the U.S. public favoured a scenario labelled "the environment is more important than growth" rather than the opposite scenario (Harris survey for the U.S. Soil Conservation Service, Oct. 1979).

However, in the environment versus energy equation, the U.S. public has generally been found to favour higher environmental risks to ensure energy supplies and development. These differences in findings support the argument that the public can understand a risk-benefit balance, and can discriminate between alternative tradeoffs.

The risk-benefit tradeoffs for nuclear power include both environmental and health impacts. It is to be expected that human health risks are perhaps less likely to be tolerated for lower prices than environmental harm. The public view of the risk-benefit equation for nuclear power, if human health is explicitly included, may favor a reduction of the risks to the limit of feasibility even if benefits must be sacrificed accordingly.

2.1.4 Perceived ability to control

Starr (1972) pointed out that the accepted risk of death of many voluntary activities was higher than those considered acceptable for involuntary activities. Thus private flying is more risky than commercial air transportation, and skiing or canoeing is more dangerous than travelling by car. He estimated that the risks accepted in voluntary activities were 1000 times greater than for involuntary ones. While there has been criticism of the reliability of Starr's data, the view that the voluntary-involuntary dimension is important to risk perception is generally accepted.

Another way of describing the voluntary-involuntary dimension is the degree of perceived control over one's fate. This has been related to a personality dimension, often referred to as Internal versus External Control or I-E (Rotter, 1966). As discussed above, the perception of pattern in random events has also been ascribed to a need to perceive oneself in control of events, or at least to know when to respond to them. Thus there is an important component in risk perception whose aspects have been variously called voluntary-involuntary, the illusion of control, I-E, and perception of pattern or cycles.

For nuclear power, the voluntary-involuntary dimension operates to make the level of acceptable risk lower in terms of the probability of death or injury, because members of the public see nuclear power as involuntary, resulting from decisions taken that are beyond their individual control. Public acceptance of official decisions is influenced by how the decision is made as well as by the outcome of the decision. Social justice research in social psychology has shown that acceptability of procedures is sometimes far more important than acceptability of outcomes (cf. Rawls 1971). It would be a worthwhile endeavour to examine existing public opposition to nuclear power production to see if it is related to exclusion from the decision-making process (a procedural issue) or to the actual safety standards (a distribution issue), or both (cf. Section 2.3.4).

2.1.5 Illusion of personal immunity

From the earliest studies on perception of natural hazards, observers have remarked on the inconsistencies that have been found between risk perceptions made with reference to others and the belief that "it won't happen to me". People will agree that another flood (or hurricane, earthquake, tornado, etc.)

will occur, but explain their lack of preparation or response by saying that they will not be affected (Burton, Kates and White, 1978). Similarly, most people believe that they are better than average drivers (Svenson, 1981) and are less likely than average to be harmed by the products that they use (Rethans, 1979). A majority of us believe that we will be among the survivors of a nuclear war, and that we are more likely than the average person to live past 80 years of age (Weinstein, 1980).

Belief that we are personally immune or that "we are on the tail end of the distribution" may help to explain the many inconsistencies found between peoples' attitudes towards risks and their observed or intended behavioural responses to them.

## 2.2 Socio-economic and demographic factors

At the individual level, psychological factors influencing perception have seldom been measured in real world situations adequately to support generalizations. However, at the societal level, at least within the context of social surveys, there is evidence of broad socio-economic and demographic differences in risk perception.

The relationship is most consistent for the knowledge component of perception. Evidence from many surveys (White and Burton, 1982) for risks as different as nuclear power, food additives and acid rain, show that

(a) men are more likely to be better informed than women;

(b) younger people (19-29 years) are better informed than older ones; and

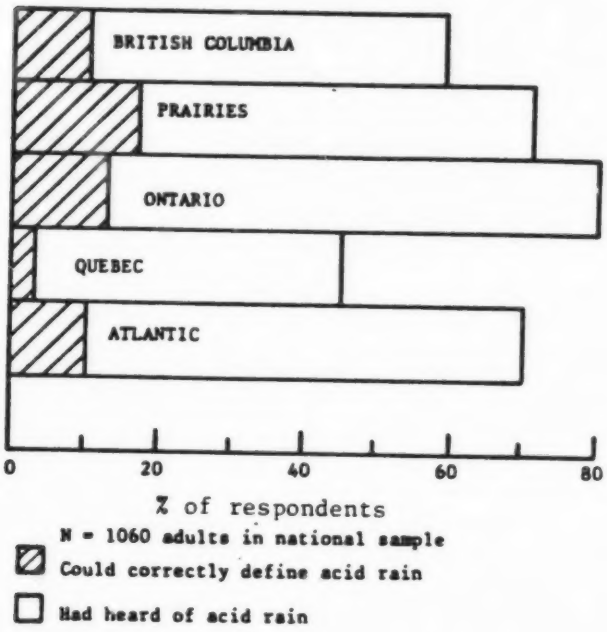
(c) people with higher levels of education are usually better informed, especially if they have had some college education.

A different and less consistent pattern is evident in the relationships between the level of anxiety (or concern) and socio-economic variables. Higher levels of education (particularly some college education) seem to be related to greater concern about the risks of toxic waste disposal, food additives, acid rain and the transportation of dangerous goods. However, the more highly educated in Canada are more evenly divided in their support of, or opposition to, nuclear power.

For many hazards women, and particularly mothers, express most anxiety. The outstanding example of this is nuclear power, but similar differences in levels of anxiety felt by men and women have been reported for food additives (Health and Welfare Canada, 1980) and for air pollution (MacCarthy and Potts, 1979).

Regional differences are not consistent across different risks. They appear to reflect broad regional differences in the environmental, political and economic context in which any particular risk is viewed. For example, in 1980 Ontarians showed the least concern for nuclear power (although they were most dependent on it) while British Columbians were most opposed to it. In contrast, a different regional pattern is seen for acid rain (Figure 3). Within Ontario or within Atlantic Canada, levels of concern are more uniform (Figure 4), although priorities on the political or public hazard 'agenda' may differ.

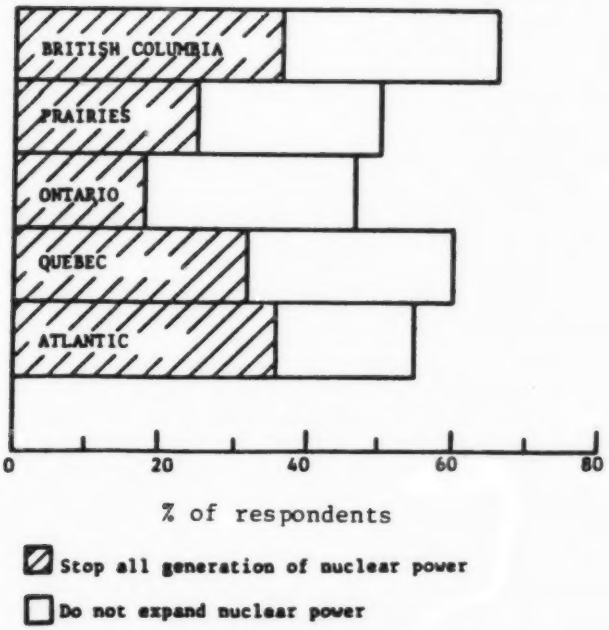
(a) Knowledge of Acid Rain




Source: Gallup News Release, October 15, 1980

1980

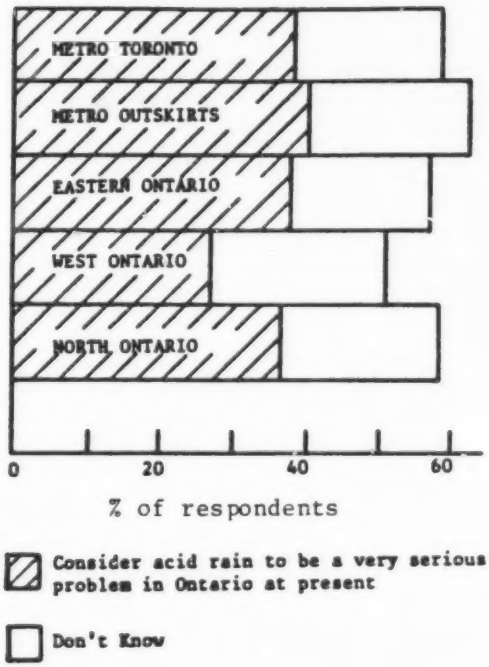
(b) Oppose More Nuclear Energy in Canada




Source: Gallup News Releases, March 8 and July 2, 1980

**Figure 3 Regional differences within Canada in (a) knowledge of acid rain; and (b) opposition to extension of nuclear power**

(a) Acid Rain




(b) Transportation of Nuclear Waste

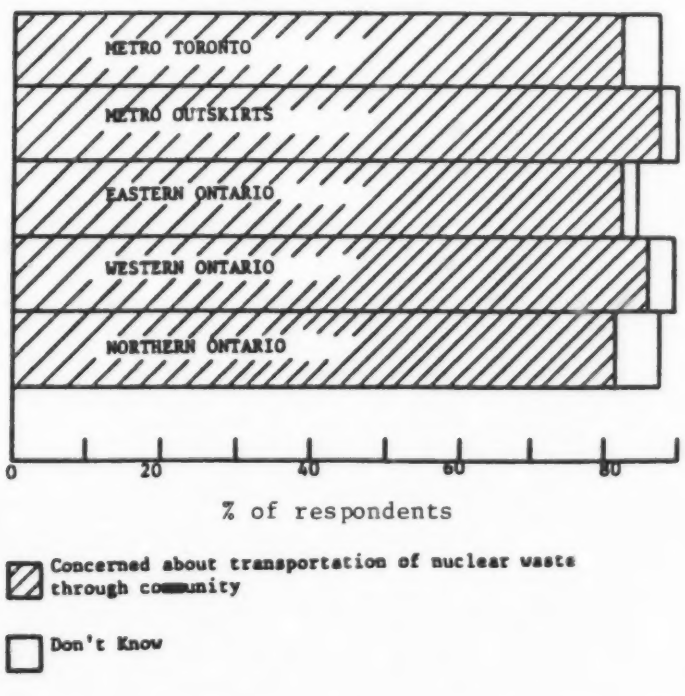



Figure 4 Examples of lower variability in risk perceptions at the sub-regional level in Ontario; (a) acid rain; and (b) nuclear waste transportation. Source: Gallup Ontario Omnibus Survey, May 1980.

## 2.3 Information factors

### 2.3.1 Knowledge versus awareness

It is important to distinguish between knowledge and awareness, both of which are contained within the term 'perception'. Awareness of a risk can mean nothing more than that a person has heard a name or term, such as 'acid rain' or nuclear power. It does not necessarily indicate any degree of understanding, or even minimal knowledge about a problem.

For example, in October 1980, a national sample of Canadians found that while 65% had heard of acid rain, only 10% could correctly say that it was associated with sulphur dioxide or oxides of nitrogen pollution (Gallup News Release, Oct. 15, 1980). Similarly, in 1980 less than 10% of Canadians polled were knowledgeable about the use of nuclear power for electricity (Gallup News Release, March 8, 1980). At the same time, time-trend data consistently show that 80-90 percent of adult Canadians are prepared to voice an opinion on national nuclear power policy. Clearly, the public does not feel that ignorance of an issue is a reason for not advocating a particular policy.

The level of knowledge being tested by social surveys is generally low; that is, one would expect more people to exhibit the minimal level required. For example, the question

> "Are nuclear power plants built near bodies of water because water is used as a power source, for waste deposit or for cooling?"

elicited only 52% correct answers in a survey conducted in the U.S.A. in 1980 (Table 1). For the other 48%, the debate about the dangers of nuclear fuel and the problems of safe waste disposal must be incomprehensible.

### 2.3.2 Direct versus indirect information

There are several types of direct information. In the first type a person can perceive a hazard directly through the senses of sight, hearing, taste, and smell. Thus, where a hazard exceeds the thresholds relating to human sensory perception, direct experience is a powerful information source.

Another type of direct information involves an individual who is the victim of a health effect, such as cancer, or who personally knows a victim. In this case, the direct experience is of the consequences of a hazard that may itself be beyond human sensory perception.

A third type of direct information reflects the directness, temporal proximity and certainty that can be attached to cause and effect. A flood that drowns, a fire that burns, and a plane that crashes are more direct in their effects than a carcinogen with latent effects appearing many years later.

In the case of indirect information, on the other hand, risk perceptions are more likely to reflect the quality of reporting and the credibility of the information source than actual levels of exposure or risk.

TABLE 1: Environmental and Energy Knowledge Questions used in a national survey in the U.S.A. in 1980 (Source: Public Opinion on Environmental Issues, 1980)

| | Environmental and Energy Knowledge Questions | | | | |
|---|---|---|---|---|---|
| | Paraphrase of question[1] | Correct | Partially correct | Incorrect | Don't know |
| 1. | What happened at Three Mile Island? (E) (Ans.: Nuclear power plant accident, close to meltdown, etc.) | 74% | 3% | 4% | 19% |
| * 2. | Do we produce enough oil or do we have to import oil? (E) (Ans.: Have to Import) | 63 | NA | 29 | 7 |
| * 3. | Are nuclear power plants built near bodies of water because water is used as a power source, for waste deposit or for cooling? (E) (Ans.: Cooling) | 52 | NA | 27 | 21 |
| * 4. | Which is the major source of air pollution: factories, automobiles or incinerators? (Ans.: Automobiles) | 45 | NA | 46 | 9 |
| * 5. | Is cancer caused in rats by every, most or only some chemicals if fed in large enough doses? (G) (Ans.: Only some) | 42 | NA | 45 | 12 |
| 6. | What are synthetic fuels? (E) (Ans.: Gas or oil made from coal, oil shale or tar sands) | 37 | 5 | 15 | 42 |
| * 7. | Is it possible for a nuclear power plant to explode and cause a mushroom shaped cloud like the one at Hiroshima? (E) (Ans.: No) | 31 | NA | 52 | 16 |
| 8. | What is acid rain? (G) (Ans.: Polluted rain that harms lakes, land and water that is like vinegar, etc.) | 26 | 6 | 9 | 58 |
| 9. | What happened at Love Canal, near Niagara Falls? (G) (Ans.: Chemical or toxic waste dump, place where chemical wastes harmed people or made them move, etc.) | 22 | 4 | 8 | 65 |

1 With the exception of Question 1, each was asked of only one half the sample
G = Part of the three-item General Environmental Knowledge Scale
E = Part of the five-item Energy Knowledge Scale
NA= Not applicable
* = Presented in a multiple choice format.

### 2.3.3 Role of mass media

For those Canadians who learn about hazards and their consequences indirectly, the mass media (television, radio, newspapers and magazines) are the principal sources of information. Television is probably the most influential single information source.

For hazards like nuclear power or organic chemical residues on food, both the degree of exposure and the link between cause and effect can normally only be obtained from indirect information sources. Thus, television is believed by nearly a quarter of the Ontario public to be "the best way to receive information on nuclear waste disposal" followed by newspapers and magazines (Gallup Ontario Omnibus Survey, June, 1979). Altogether, the mass media are regarded as the best information source on nuclear waste disposal by 84% of the public.

One of the functions of the mass media is to distribute information from official sources to a wider audience, but the information that finally appears is selective; it is usually accompanied by evaluative comment and is put in a particular context. The mass media, moreover, seek to capture the broadest possible audience; they aim less to inform than to entertain. All this changes the impact and meaning of the message. The biases that are often criticized in media reporting (focus on rare events, large consequence events, dramatic stories, 'big bang' events with strong visual images) are but the lay person's perceptual biases writ large. Thus, media reporting exaggerates the intuitive biases of risk perception.

Fictional accounts of hazards may have more impact on perception than reported news, especially since fiction aims to elicit maximum emotional response in the audience (e.g., 'The China Syndrome').

### 2.3.4 Credibility

An important aspect in the reception of information is how credible it is perceived to be. Although the public may recognize that journalistic accounts of events can be biased, they often feel that "there is something in them". For communications from governments, official agencies and the private sector, credibility is more critical.

Nuclear power is a pre-eminent example of the credibility problem in which the mass media are believed more by the public than are federal and provincial governments and agencies (Table 2). University scientists are regarded as the most credible source although only 1% of the public feel that they are the best source (because they are not generally accessible to the public).

TABLE 2: Public opinion in Ontario on the credibility of information sources about nuclear waste disposal in 1979*

| Source | All Ontario |
|---|---|
| University scientists | 72% |
| Television news reports | 68 |
| Newspapers | 59 |
| AECL | 59 |
| Environmental and conservation groups | 56 |
| Ontario Ministry of Energy | 48 |
| AECB | 49 |
| Federal Ministry of Energy | 50 |
| Ontario Hydro | 44 |
| Members of Parliament | 27 |

*Response of "very believable" or "quite believable" to the question: "I am going to read you a list of information sources about nuclear waste disposal. I would like you to tell me how believable you think the information you receive from each source is".

Source: Gallup Ontario Omnibus Survey (1979)

In general, the trust in governments in North America has been declining, and this affects the way the public views governmental action in relation to chemical and other risks. For example, the trust in government in the U.S. has declined dramatically between 1964 and 1982 (Figure 5). A similar trend may be conjectured for Canada.

An analysis of the reporting of causes of death over a one-year period by two U.S. newspapers (one in Massachusetts and one in Oregon) found that many of the statistically important causes of death (e.g. diabetes, emphysema, various cancers) were rarely reported. However, relatively rare violent events such as tornadoes, fires, and homicides were more frequently reported. Diseases take 16 times as many lives as accidents in the U.S.A. but the two newspapers reported accidental death 3-7 times as often (Combs and Slovic, 1979).

The same study found that the correlation between people's judgments about the frequency of death from various causes and newspaper reports (holding statistical frequency constant) was 0.89 and 0.85 for the two newspapers. Although intuitive risk perceptions can be related to newspaper reports, the direction of the relationship is not known. Do newspapers reflect intuitive biases of the public or help to create them?

A current study being coordinated by the International Atomic Energy Agency (IAEA) on newspaper coverage of nuclear power in the major newspapers of 17 countries includes Canada. Preliminary results indicate that the frequency of articles in the Globe and Mail is high. Later analyses will examine the content and evaluative components.

2.3.5 Public access to information

Burton and Whyte (1977), reporting on the use of risk assessment in policy decisions on nuclear power, concluded that the climate of confidentiality in which nuclear safety matters are conducted in Canada was becoming counterproductive. Unlike the U.S. where an adversarial relationship, open to public scrutiny, exists between regulator and regulated, Canada has a more cooperative approach from which the public is largely excluded. Such differences are somewhat a matter of national governmental style and must be judged in the context of the entire political system as much as the particular industrial situation.

So far the Canadian approach to regulation has served the needs of the industry and has effectively protected the public, but a climate of confidentiality seems to confirm to the public that the nuclear industry has information about risks which it is unwilling to share. Simply opening office files, however, is of little use to the public in complex technical subjects. The public also needs competent advice on what are the most appropriate questions to ask in relation to special public concerns. Next, they need advice on the meaning of the masses of data. Paying an expert to start from scratch is inefficient. The public needs advice and support from someone who is already familiar with the subject, who can be trusted and who is willing to help.

2.3.6 Expectations of government

Many surveys include questions to probe the public's expectations of government and to find where the public believes responsibility for risk management rests.

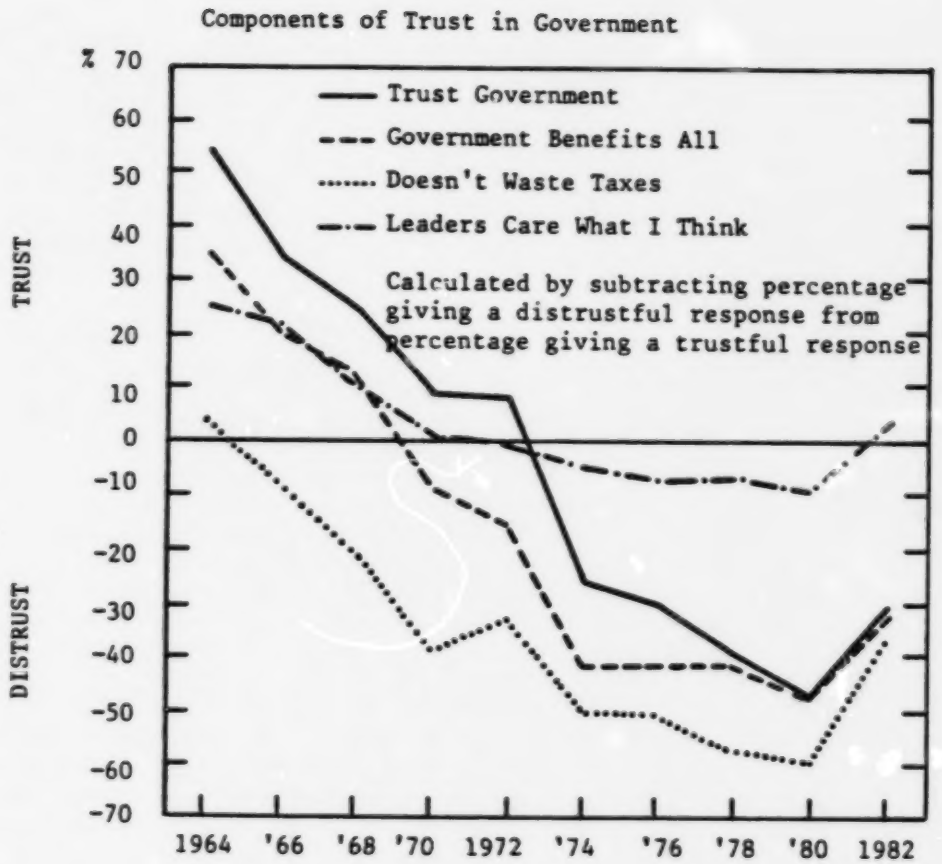



Figure 5 Decline in public trust in government in government in the U.S.A., 1964-82 (ISR Newsletter, 1983).

There is a mismatch between public expectations of the federal government's capability to solve major national problems and public ratings of past government performance. Canadians seem simultaneously to hold high expectation and to overrate the power of the federal government to solve problems while consistently giving negative ratings to the way government has handled problems like inflation, energy and unemployment. Provincial governments are generally given about 20% higher satisfaction ratings by Canadians than the federal government (Decima, 1980-1983).

Many Canadians (69%) see the need for major changes in government operations and to a lesser extent in the individual's social role (38%). An increased belief in individualism seems to be emerging with 87% of Canadians in 1983 believing that individuals should take a more active role in government and 84% believing that individuals should "look out for themselves". This decline in confidence in public institutions includes industry and 'big business'. Oil companies, multinationals and chemical companies are among those industries that have consistently received negative ratings since 1980 (Decima, 1980-1983).

2.3.7 Cumulative information

In 1960, or even in 1970, the terms 'risk assessment' or 'risk perception' were unknown to the public. In the 1980s they appear in newspapers and are heard on radio and television. This new information makes the public more aware of risks and tends to give the impression that risks are increasing. As each wave of hazards to health and environmental crises successively hits the headlines, the public is bombarded with information about industrial irresponsibility, government lapses or incompetence. They are told of increased hazards in the home, on the road, at the workplace, and even in their food and drinking water. Within 10-15 years, the public has become sensitized to risks and has come to recognize them as being part of everyday living.

A study in the U.S.A. shows that people today believe they are more risk conscious than in the past (Marsh and McLellan, 1980). Almost 80% of those asked believed that risks to society are increasing (Table 3) and that the U.S. public is more aware of risk today (Table 4). Risks from energy sources rank fourth among those which the public believe represent a greater exposure to risk today than 20 years ago (Table 5).

TABLE 3: Perception by US public of increasing risks to society in future (from Marsh and McLellan, 1980)

| | n = 1,488<br>% |
|---|---|
| Risks to society will be: | |
| Greater | 55 |
| Less | 18 |
| About the same | 22 |
| Not sure | 5 |

TABLE 4: Perception by US public of public sensitivity to risk (from Marsh and McLellan, 1980)

| | n = 1,488 % |
|---|---|
| US Public is: | |
| Overly sensitive to risk | 15 |
| More aware of risk | 78 |
| Both | 2 |
| Not sure | 5 |

TABLE 5: Areas in which U.S. public perceived greater exposure to risk in 1980 than 20 years earlier (from Marsh and McLellan, 1980)

| | % saying risk is greater today (1980) n = 1,488 |
|---|---|
| Crime and personal safety | 85% |
| The chemicals we use | 81 |
| International political stability | 73 |
| Energy sources | 71 |
| Methods of travel | 62 |
| Domestic political stability | 61 |
| Water supply | 60 |
| Personal financial security | 59 |
| Food supply | 56 |
| Household products | 52 |
| Medical care | 32 |
| Occupational safety | 31 |

Crises, and particularly major accidents, appear to have both short-term and long-term effects on risk perception. For example, the nuclear reactor accident at Three Mile Island (April, 1979) had a more dramatic short term effect in increasing public opposition to nuclear power in Ontario, than it had in the long term (Figure 6).

The longer term effect of crisis events is cumulative, not only to increasing public concern about risks within a category (e.g. nuclear, pesticides), but also across all risks. Thus, a study of the effects of the November, 1979 Mississauga derailment near Toronto on risk perception found that, compared to a control group, evacuees had a higher expectation of a major nuclear accident happening in Ontario within the next 10 years. The accident experience had thus increased their sensitivity to other, unrelated hazards (Burton, Victor and Whyte, 1981).

Experimental data confirm this finding. Students exposed to manipulated newspaper reports of deaths by leukemia, fire, and crime had increased subjective probabilities for death from a number of unrelated causes (Johnson and Tversky, 1983).

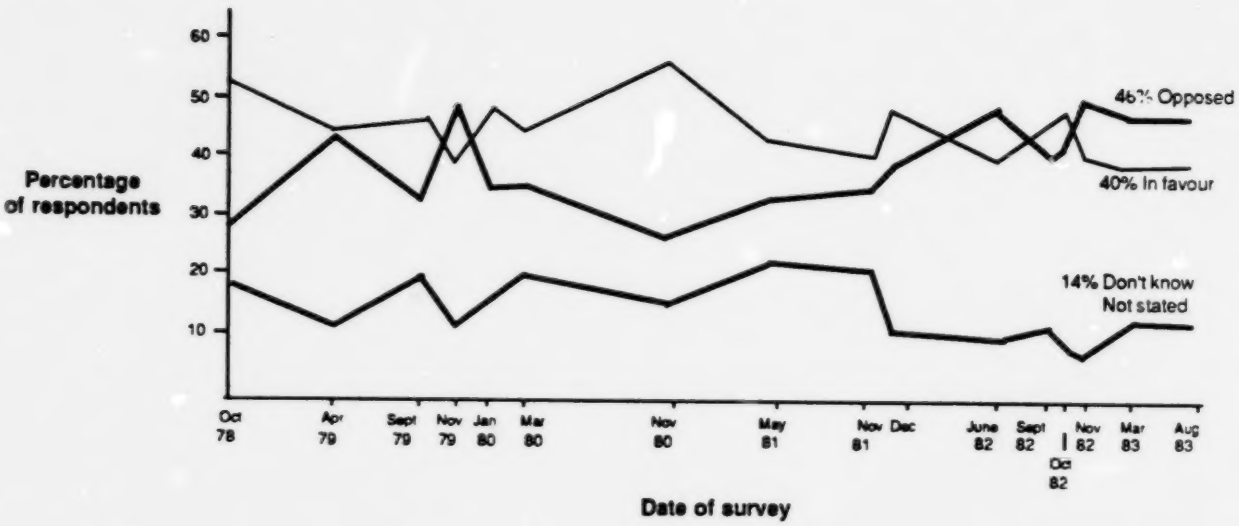



**Figure 6: Public view of nuclear power (After AECL, 1984).**

Reporting of risk events often focusses on government action or inaction. Thus, current public expectations of government are also a function of the past history of risk management.

## 2.4 Culture and risk perception

Psychological and sociological studies of risk perception employ experimentation, random sampling and surveys, and consider the behaviour of individuals or collections of individuals as samples drawn from a homogeneous set of people. In contrast, anthropological studies traditionally employ methods of field observation, and presuppose that the observed behaviour reflects culture to a great extent. Lay people think of culture as national or regional, and talk of "North American Culture" or "Canadian Culture", for example. The anthropologist, however, sees these as vague pseudo-entities. There is a diversity of cultures within such regions or nations, and they proceed to describe cultures as determinants of behaviour.

Douglas (1978) has proposed a general theory of cultural bias that postulates two important dimensions of culture, called group and grid. This theory provides a different insight into risk perception. The group/grid classification has been applied and further developed in several studies by others, notably Thompson (1984) and Wildavsky (1979) in relation to risk perception and risk attitude. Douglas and Wildavsky (1982) hold that hazards and risks are not perceived, but rather chosen by a cultural process. They cite witchcraft as an example, pointing to many parallels between the processes of detecting and controlling witchcraft in the 14th-17th centuries in Europe and health hazards in the 20th century. They argue plausibly that there is a parallel between the professionals once engaged in the witch-hunting business and today's professionals in the risk-management business.

This particular perspective within anthropological work is significant for the present topic in three ways. First, cultural aspects are a priori important factors in risk perception and risk acceptance. They may be crucial for the development of policy. Second, the group/grid framework represents public risk perception in a less simplistic perspective, differentiated according to sociological variables which in part may permit explanation of otherwise contradictory features of risk perception. Third, the theory relates risk perception to the more general political objectives of the subcultures, and allows the expression of risk perception to be considered as one among many other tools to achieve particular ends. This places risk perception directly in a game-theory setting, and allows it to be studied as an object of manipulation. Indeed, psychological and sociological studies that ignore this manipulative aspect of risk perception data may, in retrospect, seem incomplete.

Thompson has further developed the two-variable culture model, introducing the simplifying notion that there are just five distinct and stable cultures, i.e. rationalizable ways of life. Each of them is supported by a distinctive idea of nature, Thompson (1984). These cultures can be located on the group/grid plane as shown in Figure 7.

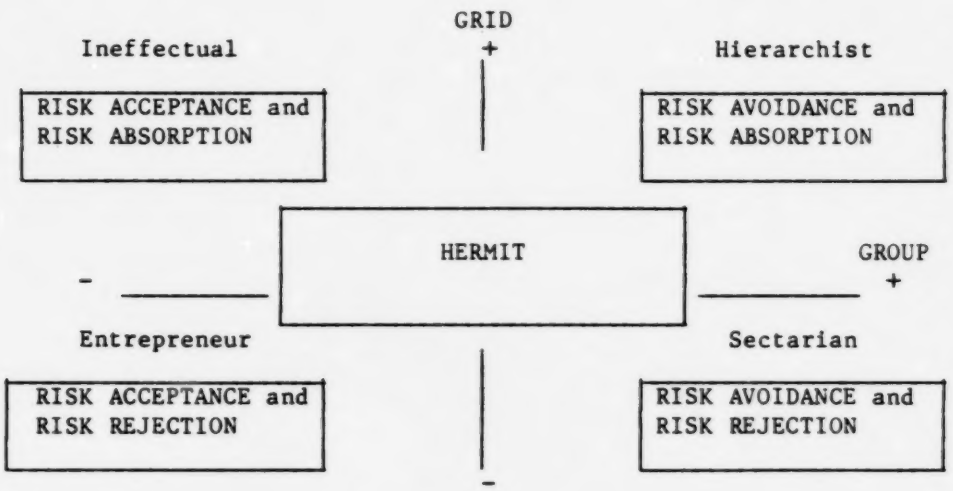



Figure 7 Five cultural contexts and attitudes to risk.

As can be seen in Figure 7, one distinction that can be made between two attitudes to risk is between risk acceptance and risk avoidance. This describes one dimension of risk-handling that, in terms of the cultural bias hypothesis, lies along the group axis. A second dimension, corresponding to the grid axis, describes two risk-handling modes that are altogether different. These two modes are labelled risk rejection and risk absorption. With these two dimensions it is possible to describe five distinct socially induced styles of risk-handling that individuals, by virtue of their social contexts, will be predisposed to adopt.

(1) The autonomous individual - the 'hermit' - adopts a risk-handling style characterized by the acceptance of his own risk. His strategy of deliberately avoiding socially coercive involvement results in the risks he

takes remaining closely attached to him. Unlike (say) the 'entrepreneur', he cannot offload some of them onto somebody else.

(2) The social context of the 'entrepreneur' is strongly individualized and this predisposes him to see risk as a concomitant of opportunity and to accept risks willingly along with benefits: "Nothing ventured - nothing gained".

(3) The 'ineffectual' (life-is-like-a-lottery) accept risk as a face of reality; their socially induced style is one of both risk acceptance and risk absorption.

(4) The hierarchical 'caste-ist' context encourages risk avoidance but predisposes its occupants to risk absorption, sharing the risks they cannot avoid. Hierarchists are not reluctant to set acceptable risk levels. Moreover, they are prepared to countenance setting them at quite a high level.

(5) The 'sectarian' social context encourages risk avoidance but does not encourage risk absorption. The strategy widely known by the acronym "NIMBY" ("Not In My Back Yard") is sectarian.

The theory predicts that only three of these groups (hierarchists, entrepreneurs and sectarian) will participate in any policy debate (Thompson and Wildavsky, 1982). Six independent empirical accounts of such a tripartite division of world views, in the literature ranging from engineering to political science, have been found by Thompson (1982). Risk perception in this theory is not independent, but a part of the specific world view. It is part of the coping strategy and can be understood and predicted from the particular cultural bias.

## 3. MODELS AND THEORIES OF RISK PERCEPTION

Von Neumann and Morgenstern (1947) first proposed a general theory of rational choice. Although this theory is normative, it opened the study of why some people in some situations appear to be risk-takers, while others (or the same people in other situations) appear to avoid risk.

Many studies since 1947 have tried to describe risky behaviour as decision-making under conditions of uncertainty. These studies have been framed within the general area of economic decision models which emphasise the limitations to human information processing. But apart from the errors in probability judgment and differences in the values certain gains and losses hold for people, which these studies examine, there are clearly attitudinal differences between people in relation to risk.

Thus, general attitude theory in psychology can also be applied to risk perception, with its notions of the need for balance and consistency between attitudes (Fishbein, 1967) and the attitude adjustments that are made when the individual recognizes inconsistencies (cognitive dissonance: Festinger, 1957). Indeed attitude to risk is one of the first attributes of a person that comes to mind when one has to describe someone's personality (Fischhoff et al, 1981). Pieroni (1981) argues that for the public "nuclear power holds a unique position in terms of images, and the emotions the energy source generates". There appear to be six dimensions along which risks and benefits of energy sources can be compared: resource reserves, cost, pollution, experience (e.g. proven, visible,

personal comfort, political uses of fuel, and danger. However, the meaning of the dimensions differ when applied to conventional or to nuclear energy, according to Pieroni (1981). Each dimension has a distinct associated component of risk, making comparison difficult.

Slovic (1962) compared the scores of individuals on nine different measures of risk taking and found no consistency at all: People who are daring in one context may be timid in another. This has been confirmed in numerous other studies. Fischhoff et al (1981) associate this with the fundamental attribution error, the tendency to view ourselves as responding sensitively to the demands of varying situations but to see others as driven to stereotype behaviour by traits of personality (Nisbett and Ross, 1980).

Risk perception clearly includes not only cognition (information processing) but also affect (= emotion, feeling). Studies that have included affect measures (worry, concern, fear) show that affect about hazards makes a contribution to perceived risk over and above perceived risk likelihood. Moreover, the perception of nuclear power risks, which are known not through direct experience but through information, is likely to be powerfully shaped by interpersonal feelings, and by social grouping. Above all, the individual's personality and experience will help to determine the attitudes expressed and the choices made. Thus, much of the psychological and sociological theories of attribution, interpersonal and group social processes, and personality can be applied to the understanding of risk perception.

It is small wonder, therefore, that when risk perception is studied in the real world away from the hypothetical decisions of experiments and surveys, it becomes very difficult to predict.

Another model that has been proposed in relation to risk is that of risk "homeostasis" (Wilde, 1982). The notion here is that we all have a fixed amount of "worry beads". Once these have all been counted, the total cannot be increased; but one worry can be substituted for another (Kates, 1978). Another aspect is that each of us has a comfortable level of risk that may vary in absolute terms between individuals and cultures.

If our perceived risk exposure exceeds the desired level, we act to reduce our exposure to risk. This homeostasis model for risk may help to explain the observation that drivers wearing seat belts tend to drive more recklessly (closer behind other cars and at faster speeds). This point has recently been challenged (Lund and Zador, 1984).

One of the important questions in risk perception is whether the findings for natural hazards apply also to man-made, or technological risks. The critical issue here is the assignment of responsibility. The traditional distinction between 'natural' and 'man-made' hazards is more blurred than was initially assumed. The perception of pattern in natural events may result from either or both of two processes; the belief that some force is influencing them, and that that force has purpose and motivation; and the desire to feel that one has some measure of control over these events. For natural hazards, the influential force may be viewed as supernatural; increasingly, in modern societies, it is seen as a natural process compounded by human choice. Thus floods in the U.S.A. tend to be viewed by the public more as caused by engineering and zoning decisions than by 'acts of God' (Burton, Kates and Whyte, 1978).

Because the burden of all technological hazards and the required regulatory effort is large in modern society, some attempts have quite recently been made to model the nature of all hazards in terms of generic characteristics. Several examples are quoted by Hohenemser, Kates, and Slovic (1983), who also themselves have produced a comprehensive model of hazard description. They order the hazard descriptors along the causal chain of technological endeavour (human needs → wants → choice of technology → release of material or energy → exposure → consequences). They identify 12 descriptors (intentionality; spatial extent; concentration; persistence; recurrence; population at risk; delay of consequence; mortality; maximum potential killed, transgenerational; and nonhuman mortality, potential and experienced). Ninety-three hazards were scored on scales of these descriptors by reference to literature and specialists.

The analysis reveals a striking distinction between energy hazards and material hazards, in terms of duration of release, immediacy of consequences, transgenerational effects, and nonhuman potential mortality. Using principal component factor analysis they derived five orthogonal composite dimensions that account for 81 percent of the variance of the responses. The structure of each of the 93 hazards can thus largely be described by these five rather than 12 variables. The five factors have been called "biocidal", "delay", "catastrophic", "mortality" and "global" (Figure 8).

Hohenemser, Kates and Slovic also tested a small sample of the public (34 Oregonians), determining for 81 of the 93 hazards their judgment of perceived risk and their ratings of the 12 hazard descriptors. They reported that the perceptions showed little correlation with the experts' descriptor ratings, which only explained some 50 percent of the variance. Particularly striking is the absence of correlation between mortality and perceived risk. "Thus, the variable most frequently chosen by scientists to represent risk appears not to be a strong factor in the judgment of our subjects". However, these people's perceptions were highly correlated (85 percent explained) with the average of their <u>own</u> ratings of the 12 hazard descriptors. This suggests that the hazard descriptors are well understood by nonexpert subjects, and that they do reflect the essence of perceived risk. Hohenemser <u>et al</u> are themselves the first to point out that larger and more representative groups must be tested before the results can be generalized. They proceed to show several practical applications of their results. Of particular interest for models of risk perception is the comparison of technologies. They write:

> Basic to hazard management are comparisons and choices among competing technologies. For example, for electricity generation, coal and nuclear power are frequently compared, and the hazards of each are invariably couched in terms of mortality estimates. Inhaber has estimated that mortality rates associated with coal technology are 50 times those for nuclear power technology (Figure 8). Such one-dimensional comparisons have created considerable dissatisfaction because they ignore other important differences, including other aspects of hazardousness between the two technologies. Our factors and descriptors for hazardousness offer a partial solution by allowing a multidimensional hazard profile to be applied to coal and nuclear power (Figure 8). This profile was obtained from combined descriptor scores for each of several hazard chains that make up the total hazard of coal and nuclear power. Coal still exceeds

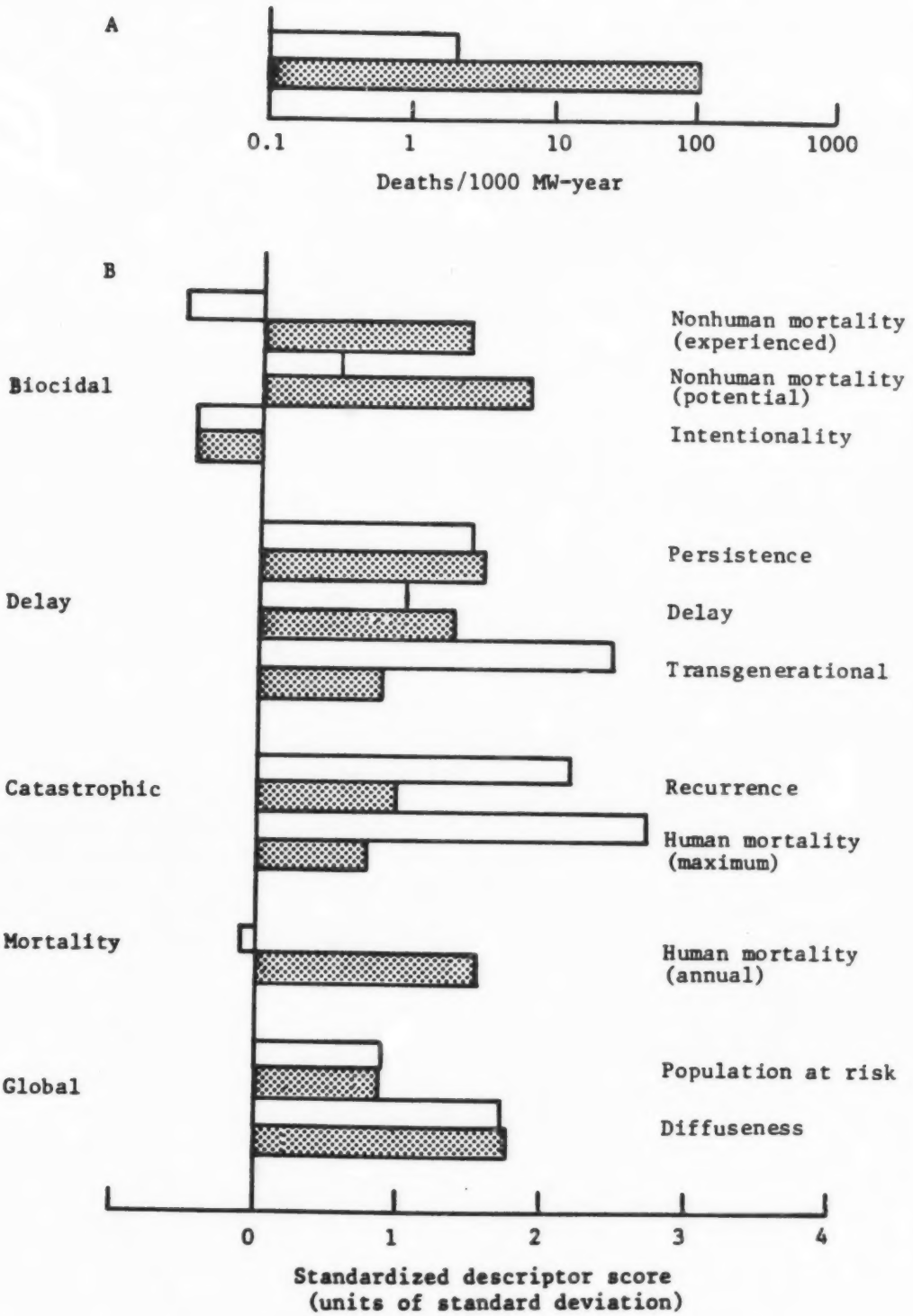



Figure 8 (after Hohenemser et al. (1983)). Comparison of nuclear (light bars) and coal-fired (black bars) electric power by using Inhaber's analysis (A) and our hazardousness factors and descriptors (B).

nuclear in human mortality, as expected from Inhaber's analysis, and it also exceeds nuclear in nonhuman mortality, that is, environmental effects. Nuclear power, on the other hand, dominates in possible transgenerational effects and the catastrophic factor. The two technologies show little difference in persistence, delay, population at risk and diffuseness.

The profile of hazardousness developed from the 12 hazard descriptors seems to capture the complexity of choice in energy risk assessment and management better than the common mortality index. The problem of choice remains, as does the question of how should society weight the different dimensions of hazardousness.

One direction for future research in risk perception would be to study public assessment of the five factors shown in Figure 8 for nuclear and alternative sources of energy. Comprehensive models of risk perception are still under development. Most of the models discussed in this report are simply extensions of existing social theory.

## 4. MEASUREMENT AND OBSERVATION OF RISK PERCEPTION

### 4.1 Methods of accumulating data

Data on risk perception have been obtained primarily through three methods;

(a) laboratory experiments such as those conducted by social psychologists on heuristic biases;

(b) field studies, such as those carried out by geographers on perception of natural hazards in tornado zones, flood plains, etc.;

(c) social surveys, such as those conducted by sociologists; and public opinion pollsters on national samples of the population.

Each of these methods brings with it various strengths and weaknesses that limit the usefulness of existing perception data when applied to economic accounting models and to policy formulation.

#### 4.1.1 Laboratory experiments

In a laboratory setting, the variables of the risk decision can be simplified and manipulated to isolate and test individual dimensions of perception, such as the anchoring effect (section 2.1). When similar effects are found to be repeated under different experimental conditions, one can with some confidence accept that such an effect exists generally. However, some repeatedly observed effects, such as "risky shift" in small group decision-making are now believed to have been an artifact of the experimental situation rather than reflecting any real world phenomenon. The main limitations of experimental data are that:

(a) they fail to predict outcomes when all variables are changed in combination, as they are in the real world;

(b) they have tended to focus on the probability component of risk perception, whereas other evidence would indicate that perceived differences in consequences are more important to public perception of risks;

(c) they tend to use university students as subjects and small numbers of subjects so that any generalizations to the public as a whole should be made with caution; and

(d) the experimental setting is itself an artificial one; subjects are not facing real decisions and even where monetary rewards are involved for 'right' decisions, the values of these do not adequately represent the value of avoiding death or pain to people in real world decisions.

The main advantage of experimentation is that it facilitates the determination of causal relations between variables. If the goal behind a study is to effect an attitude change by public education, then causal directions must be identified.

4.1.2 Field studies

Field studies study people in real life situations. Many empirical projects have studied perception of natural and man-made hazards from the point of view of those at risk, such as, for example, those people whose residences are located in actual or perceived hazard zones (e.g. coastal flood plains subject to hurricanes; residents around nuclear reactors or along transportation routes for dangerous goods; residents of areas with high air or water pollution levels).

The main limitations of many (not all) of these studies are:

(a) their inadequate sampling frames and procedures which are the result of cutting costs but which may limit their validity for larger populations;

(b) their focus on one hazard, rather than "all hazards at a place" and the definition of that hazard by the researcher rather than by the population. This approach has been known to measure perceptions of air pollution or earthquake risk for people who were unaware that the hazard existed before the interviewer came along;

(c) their emphasis on the individual as the decision-maker and their relative neglect of the social dimensions of decision, particularly the household or family.

4.1.3 Social surveys

Social surveys are conducted by sociologists and public opinion pollsters on samples of the population. The main strength of social surveys is their sampling methodology and their generalization to large populations, such as the entire Canadian public. Their limitations are similar to those of field studies except that they are even more severe. Field studies usually use, face-to-face, a questionnaire schedule that includes a large number of open-ended questions and even simple projective tests to probe explanatory variables for the perceptions measured. Their focus on one hazard, while it may bias responses in one direction, does provide a coherence and logic to the interview that can be grasped by the respondent.

Social surveys, on the other hand, may include a wide range of items that bear no relation to one another. The respondents may be asked their opinion on the safety of nuclear power, the use of forest sprays, whether they think the government is doing a good job in relation to unemployment, foreign policy, and so on, in rapid succession. There is no context to these questions and responses, beyond basic independent demographic measures like age, sex, education, and income.

There is no independent measure of respondents' exposure to risk, as there are in localized field studies, and absolutely no social context in terms of the household or larger decision-making unit. Economic measures, such as "willingness to pay", which are sometimes included in several surveys, are as hypothetical to the respondent as are experimental situations. They clearly measure something but it is not "willingness to pay" in terms of a real willingness (or ability) actually to hand over the money.

## 4.2 Canadian data on nuclear issues

### 4.2.1 Laboratory studies

The ACNS is not aware of any experimental studies in Canada of public risk perception in relation to nuclear power.

### 4.2.2 Field studies

Pieroni (1980 and 1981) conducted discussions with groups of approximately 10 members of the general public of Toronto, Thunder Bay, and Kingston in an effort to gain a Canadian perspective on public attitudes towards nuclear power production. Cautioning that the work was only exploratory because of the small sample size and the methods used to recruit the subjects, it was found that previous research on "risk" did not fit the feelings expressed by the respondents. The author reported a general disillusionment with large institutions and with the "technological fix", a feeling of impotence with respect to institutional decisions, and an increased "fear of the unknown" and disbelief in institutional guarantees. Specific disadvantages of nuclear energy were cited as catastrophic consequences of possible malfunction and concern over long-term harm from nuclear waste. These perceived disadvantages appear to dominate over the perceived advantages, and it would be difficult to shift these perceptions, she reports. These attitudes have been developed from specific incidents abroad (Hiroshima, TMI etc.) and deepened by a feeling of secrecy about the activities of nuclear institutions. The tenor of the verbatim excerpts from the discussions seems uniformly opposed to nuclear power. Pieroni's groups do not seem a likely random sample from a public that, at the time, was strongly in favour of the use of nuclear power according to the public opinion polls published by AECL (1984). Since the method of sampling ("recruitment by means of a referral method, in which they are known to members of the community and are asked to participate ...") is difficult to evaluate, it is quite possible that the results are not representative of the general public. Nevertheless, they may plausibly represent a large segment of the public.

Previous studies, mainly in the U.S., have assumed that people perceive all risk objects in the same way. Pieroni concludes, however, "that the term 'risk' is misleading because the common definition of 'risk' is placing something on the line which may have both negative and positive consequences [...] which can be evaluated by the person [taking the risk]; however, a number of 'risk' objects do not have both positive and negative consequences for the person, and thus do not involve 'chance' or 'risk' in any way." It is suggested that the general public in the discussion of risk is likely "more concerned about 'threat' or the consequences of an event, no matter its chances of occurring. Thus attempts to compare different 'risk' objects were met with incredulity or amusement". The author conjectures that the perception of "risk" or "threat" of an object and the consequences of an object malfunction result in a complex multi-dimensional grouping of such objects quite contrary to received wisdom (e.g. Slovic,

Fischhoff and Lichtenstein 1982), which places all risk objects in a continuum of two or at most three significant dimensions. Pieroni points out that to ignore this may produce a fundamentally wrong framework for the study of risk perception. If, as this work suggests, risks are perceived in disjoint categories rather than in a continuum as most research supposes, the current research methods may indeed be biasing the results (Greer-Wootten, 1984).

Pieroni (1981) observed a general perception that the nuclear industry has done a poor job of conveying to the public the benefits of nuclear energy. A large number of people are either unaware of, or reject, any positives that might be associated with nuclear energy. It was concluded, however, that the public clearly wants to hear what is good about nuclear energy.

In a study undertaken for the AECB, Burton and Whyte (1977) interviewed experts in the industry and regulatory agencies and, as well, conducted small-scale questionnaire surveys of residents around the Pickering nuclear power plants and in Toronto. They concluded that public assessment of nuclear power is extremely critical when compared with other technologies. The subject excites a high degree of public scrutiny and controversy, seemingly because of associations with nuclear war; the unique threats of core meltdown, the possibility of widespread and long term contamination associated with long-term waste disposal sites, and terrorism and sabotage; anxiety generating associations of carcinogenicity and genetic damage; and for other reasons. In spite of this extremely critical attitude, they observed that nuclear power still enjoyed a substantial majority of public support.

Now, seven years later, this majority has dwindled, but there is still significant support. The decline is not as drastic as in the U.S. where well-organized and articulate anti-nuclear groups have been more active. Burton and Whyte suggested that public support for nuclear power is volatile, and that this is the major risk that the nuclear energy programme faces in Canada. Burton and Whyte conclude also that scientific and public perceptions of nuclear risk are very differently based, and that there is a need to bring them closer. Scientific thinking is dominated by the perception that all risks can be analyzed and reduced to an acceptable level by engineering control. The Canadian public, in contrast, has little knowledge of the risks. So far, the public has accepted that risk management be left to technical and political decision makers, but this public confidence has been eroded by revelations about performance, by sensational incidents, and by contagion from the U.S. They concluded that under these circumstances the climate of confidentiality should be replaced by one of open information exchange.

As part of an international comparative study, 626 residents around nuclear power plants were interviewed (150 in Canada; 187 in the UK and 289 in the U.S.A.). The interviews included short projective tests designed to elicit people's images and associations with nuclear power (Whyte, 1977). Local residents in all three countries expressed more confidence in the inherent safety of nuclear power as a technology, and in existing safety precautions, than did the general public. The local nuclear power stations produced associations with benefit and progress for more people in Canada (42%) than in the U.S.A. (31%) or in the U.K. (29%). For another 20-30% in each country, nuclear reactors were associated with fear (Table 6). To a slightly different sample of 548 residents, radiation was a more threatening concept than nuclear reactor but, even so, 20% of the local residents studied in Canada had no frightening associations with the word, and a further 8% thought of energy,

TABLE 6: Responses to sentence completion tests about nuclear reactors and radiation by public living near nuclear power stations in Canada, U.K. and U.S.A. in 1975 (Whyte, 1977).

When I think of the nuclear power station, I feel --

| Sentence Completions | U.K. % N=187 | Canada % N=150 | U.S.A. % N=289 |
|---|---|---|---|
| - good about benefits, progress | 29.4 | 42.0 | 31.4 |
| - fear, concern | 32.7 | 22.0 | 26.7 |
| - neutral | 14.9 | 14.0 | - |
| - uncertain, confused | 2.7 | 7.4 | 5.5 |
| - nothing | 11.9 | 11.3 | 11.0 |
| - no fear, concern | 7.4 | 0.7 | 14.6 |
| - other | - | 2.6 | 10.8 |
| TOTAL | 100 | 100 | 100 N=626 |

When I hear the word radiation, I --

| Sentence completions | U.K. % N=187 | Canada % N=150 | U.S.A. % N=211 |
|---|---|---|---|
| feel - concern, fear | 39.1 | 36.7 | 43.1 |
| - no concern | 18.7 | 20.0 | 9.5 |
| think of - illness (cancer) | 9.6 | 6.4 | 10.0 |
| - energy, progress | 18.7 | 4.7 | 8.5 |
| - medical uses | 4.3 | 3.3 | |
| - bombs, war | 6.4 | 8.5 | 27.5 |
| - nuclear reactor | - | 2.6 | - |
| other - | 3.2 | 14.0 | 1.4 |
| TOTAL | 100 | 100* | 100 N=548 |

* Ed. Note: The reason for the discrepancy between 100 and the actual total of the column (96.2) is not known.

progress and the medical applications of radiation. Less than 3% of those in the study directly linked radiation to their local nuclear reactor. The most striking national differences in mental associations were found for radiation: 30% of the U.S. residents thought of bombs and war whereas only 9% of the Canadians did. Events since 1977 in Canada and internationally may have changed these perceptions.

4.2.3 Social surveys

There are more Canadian survey data on public attitudes to nuclear power than there are for any other environmental or energy issue. These data have been regularly summarized so that this report will concentrate on the more recent surveys.

When members of the public are asked what are the most important problems facing their families, their provinces, or Canada as a whole, nuclear power comes very low down on the agenda (Table 7). It is volunteered as a problem by only 1% of the public.

However, many Canadians are concerned about nuclear power. The long term data show that support has declined slightly from 1978 to 1984 (Figure 6).

Opposition has increased markedly, from 28% in October, 1978 to 38% in February, 1984. Only in Ontario is there now a majority of the decided public (48%) in favour of nuclear power generation. Over the years, the demographic pattern has consistently been that more men than women are in favour.

TABLE 7: Environmental and energy issues seen by the public as problems facing their province

(a) Atlantic Canada 1979 (Source: Environment Canada, 1980)

| | |
|---|---|
| ENERGY ISSUES | 5% of total |
| energy (general) | 4% |
| atomic energy | 1 |
| ENVIRONMENTAL ISSUES | 18% of total |
| pollution | 9% |
| forests | 2 |
| spray programs | 1 |
| conservation | 1 |
| spruce budworm | 1 |
| floods | 1 |
| noise | 1 |
| acid rain | 1 |

(b) Ontario 1979 (Source: Ontario Ministry of the Environment, 1979)

| | |
|---|---|
| ENERGY | 21% of total |
| energy | 20% |
| nuclear plants | 1 |
| ENVIRONMENT | 12% of total |
| acid rain | 3% |
| water pollution | 3 |
| air pollution | 2 |
| natural resources | 2 |
| pollution | 2 |

The accident at Three Mile Island in 1979 had less effect on people's attitudes to nuclear power generally than it did on their acceptance of a nuclear power plant being built near them (Whyte and Burton, 1982).

The low level of public understanding of the technical aspects of nuclear power has already been commented upon in Section 2.3.1 of this report. Early surveys in 1975 found that 65-80% of the public thought that a nuclear reactor could explode, and 20-30% did not know that uranium (rather than coal, bauxite or magnesium) is the fuel or that the word 'fission' is associated with the process of producing heat (Whyte, 1977).

The nuclear debate has made the public more aware of nuclear power and has focussed their concern on safety, leaks, waste, and health issues (Figure 9).

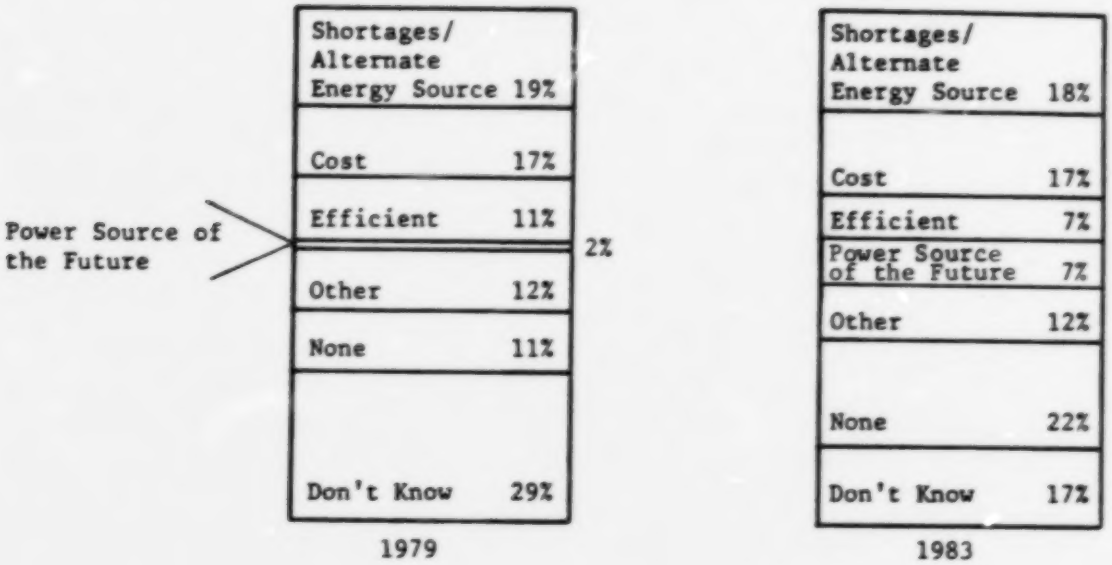
There is still confusion in the public mind about the environmental impacts of nuclear power. For example, a survey taken in Atlantic Canada in 1979 found that about 20% of those asked thought that nuclear power was "environmentally dirty" (Table 8).

TABLE 8: Public perceptions in Atlantic Canada of alternative energy sources in terms of risk and environmental pollution in 1979

| | Newfoundland and Labrador | Prince Edward Island | Nova Scotia | New Brunswick |
|---|---|---|---|---|
| Percentage of respondents saying: | | | | |
| Energy source is dangerous | | | | |
| Coal | 7.7% | 4.3% | 4.9% | 4.4% |
| Oil | 9.6 | 2.7 | 6.1 | 4.4 |
| Nuclear | 55.8 | 44.9 | 54.1 | 45.6 |
| Hydro-electricity | 1.9 | 4.9 | 2.1 | 0 |
| Tidal power | 5.1 | 1.1 | 1.6 | 1.7 |
| Energy source is environmentally dirty | | | | |
| Coal | 37.2% | 39.5% | 37.9% | 33.3% |
| Oil | 15.4 | 8.1 | 10.6 | 8.3 |
| Nuclear | 22.4 | 18.4 | 19.3 | 17.2 |
| Hydro-electricity | 1.9 | 1.6 | 1.2 | 0.6 |
| Tidal power | 3.8 | 0.5 | 0.9 | 1.1 |
| N = | 156 | 185 | 425 | 180 |

Although almost half the Canadians surveyed in August 1983 did not feel that media discussion about nuclear weapons influenced their opinion about nuclear power generation (Barrodos and Binns, 1983), it seems unlikely that there is no association of ideas, but there are no studies available to validate this important issue. The recent publicity about the problems with pressure tubes at the Pickering Reactors and the cost estimates for replacing them is also likely to have increased opposition to nuclear power by Ontario residents.

ADVANTAGES TO USING NUCLEAR POWER




DISADVANTAGES TO USING NUCLEAR POWER

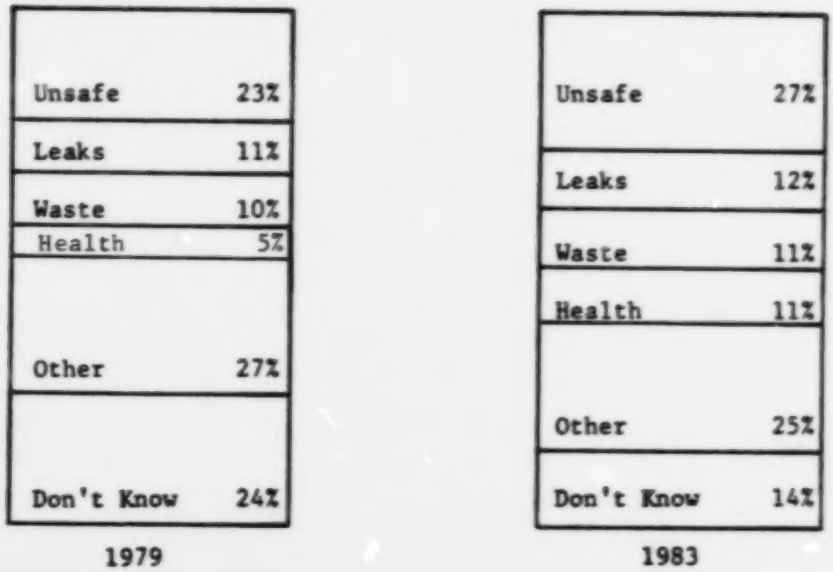



**Figure 9** Advantages and disadvantages to nuclear power volunteered by Canadians in 1979 and 1983 (Barrados and Binns, 1983).

In 1983, 61% of Canadians could give advantages to the use of nuclear power (Figure 9), but almost 40% could not cite any advantage. Since 1979, Canadians have become more likely to feel that there are no advantages (22% in 1983 vs. 11% in 1979). This trend may well have been exacerbated in 1984 by the revelation of the costs of retubing the Pickering reactors.

4.3 Scope of concern about nuclear power

4.3.1 National concerns

The scope of public concern about nuclear power is now very wide. It includes concern over the following (not necessarily in order of importance):

EVENTS: (a) major release of radiation through a reactor accident;

(b) lower, more continuous leakages of radioactive materials from reactors into the surrounding air and water;

(c) accidents relating to heavy water production;

(d) uranium mining and mine tailings;

(e) transportation;

(f) waste storage;

(g) diversion of radioactive materials to nuclear weapons;

(h) threat of sabotage;

(i) sale of nuclear technology to other (less stable) countries;

EFFECTS: (j) death (in major accident, nuclear war)

(k) cancers in exposed populations;

(l) mutagenic and teratogenic effects;

(m) environmental contamination of specific areas (through accidents, decommissioning of reactors etc.) and loss of use or enjoyment of those areas.

The perceived association between nuclear power and nuclear war is a current fact of life for the nuclear industry. Likewise, the increasing concern about cancer and teratogenic and mutagenic effects generally is likely to lead to increasing opposition to nuclear power because there is an awareness of the association between cancer and radiation.

4.3.2 International concerns

The safety of nuclear power is an important concern that transcends national boundaries. This concern takes two forms. First is the fear that malfunctioning of a nuclear power plant in one country may affect safety in an

adjacent country. Second is the concern over the ethical implications of exporting nuclear technology from Canada to countries that are perceived to be politically unstable, and this reflects on public opinion on the nuclear industry at home. Little seems to be known about the international "safeguards" that are in place to detect diversion of nuclear material from power stations to military use, nor is much known about the role Canada plays in this "safeguards" process.

## 5. SOCIAL COSTS OF NUCLEAR POWER GENERATION

In addition to the direct economic costs of mortality and morbidity which can be attributed to any hazard, there are less easily quantified psychological, social and health costs such as loss of productivity through anxiety. For example, it has been argued that for cancers (from all causes) in the U.S.A., these estimated additional socio-psychological costs can exceed the direct economic costs by a factor of 10 or more (Abt, 1975).

It is important to recognize that socio-psychological costs can exist not only when clinical health effects are present, but also when such effects are anticipated or feared. This aspect is particularly relevant with respect to "nuclear power" because of the perceived connection between it and "cancer", both of which are matters of public concern.

The social costs of cancer, exclusive of economic costs, were systematically developed by Abt (1975) who identified and estimated 25 components of this social cost, including the cost to the victim of cancer, to family and colleagues, and to care-givers. These costs were translated into monetary amounts on the basis of market costs or shadow prices of imputed costs. The process is necessarily uncertain and open to criticism of detail, but the estimates are generally so conservative as to be quite convincing. The social costs of cancer appear to be greater than ten times the simple economic costs.

A similar approach can theoretically be applied to the estimation of total costs from the public perception of risk associated with nuclear power generation, although in practice the data are unavailable and are unlikely ever to be available. Perhaps the major components of these costs would be anxiety and fear leading to productivity losses in individuals and the costs to society of confirmation and delays in decision-making.

If the socio-psychological effects of perceived risks or anticipated effects are included, the population suffering these effects is theoretically as large as the number of people who feel concerned. In this report, the purpose is not to estimate how large this population is, but to emphasise that the critical factors in determining its size are not the actual exposure patterns, but those that are perceived by the public.

It is important to remember that in discussing the social costs of the public perception of risk of nuclear power, the degree of impact is greatly influenced by the group being exposed. For example, sufferers and victims must be distinguished from others, and people who personally know a victim must be distinguished from those for whom the victims are merely statistics.

As an example of this general effect, Abt (1975) estimated the numbers of people affected by cancers, each year in the U.S.A. (Table 9). These figures are for all cancers but they include the relative proportions in two exposure groups (victims and those personally knowing victims).

TABLE 9: Conservatively estimated sizes of the different social groups exposed to psycho-social costs of cancer in the U.S.A. (from Abt, 1976)

| | |
|---|---|
| 350,000 | cancer victims exposed per year |
| 100,000 | children of victims exposed per year |
| 175,000 | spouses of victims exposed per year |
| 70,000 | siblings of victims exposed per year |
| 80,000 | parents of victims exposed per year |
| 300,000 | friends/co-workers of victims exposed per year |
| 35,000 | care givers of victims exposed per year |

The question raised here is whether such psychological effects of the public perception of risk of nuclear power should (or could) reasonably be included in the estimation of the social costs of nuclear power generation in Canada, and whether they are likely to be included in any future risk assessments of nuclear power.

More likely to be included are alienation costs. These include anger at the authorities who were presumed to be responsible for protecting people from such risks. Related responses are a decline in trust in authority, a loss in the credibility of the authorities, and a generalized political alienation from 'the system'. These responses ultimately get translated into greater costs for government as new politics and procedures are put into place to increase public confidence and communication between the public and government in order to implement risk management policies.

It has been suggested that a component in environmental concern is a widely shared view that the environment is a heritage of mankind which should be transmitted to future generations in as good (if not better) a state as it was received by the present generation. This has been described as 'bequest motivation' and is also difficult to measure. One reason people have children is to provide their link to the future. Children also provide a sense of continuity between the past, present and future, and a means of hoped-for immortality (Espenshade, 1977).

## 6. PUBLIC INFLUENCE ON NUCLEAR POWER GENERATION

The public perception of the risk associated with nuclear power has no doubt had some effect on the overall safety goals in the nuclear energy industry but any direct influence is hard to recognize in terms of system design and in the detailed regulations.

A critical public has certainly produced a considerable expansion in the information activities of both the regulatory authority and the nuclear facility designers and operators. The AECB has instituted new policies for the dissemination of licensing information. Proposals for new regulations and for new

regulatory guidelines are circulated for public comment before they are made AECB policy and much of the documentation presented in support of license applications is now available for study. Nuclear system designers have increased their activities in the field of public education and have intensified their efforts to correct erroneous statements and positions put forward by anti-nuclear groups (one must distinguish here between anti-nuclear groups and a public perception that nuclear power is not safe enough). On the factual side much more information is now forthcoming from operating experience concerning the frequency of accidents and operational upsets at nuclear generating stations.

Whether or not these activities are changing the public perception of the nuclear industry is difficult to measure, but there is little doubt that a perception of 'not enough being told' remains.

## 7. EDUCATION

The public perception of risk associated with nuclear power production is only part of the public perception of risk in general and the evaluation of uncertain benefits.

There are great needs for education of the public in matters of risk. The need is two-fold: to improve the understanding of the way in which specific decisions are arrived at, and to provide Canadians with a better understanding of the implications of risk and uncertainty. The public needs to gain an appreciation of real health risks, with a balanced understanding of the significance of personal habits (smoking, diet) and the real costs of regulation of hazardous activities.

Specifically, the public should understand the philosophy of allocating funds to achieve the greatest increase in safety per dollar spent. It should also be appreciated that there must be reasonable limits to the dollar spent per casualty avoided. This should be in harmony from one industry to another. In the relation between probability of accidents and their consequences it should be understood that there are limits to the magnitude of both variables, that the probability of the event declines more rapidly as its magnitude increases. In estimating risks and designating limits (for anything that involves biological effects), a factor of two or three is not very important. As long as the limits are reasonable, their very existence and their observance are important factors in reducing total exposures.

There is a general need in Canadian society to bring professional and public perceptions of risk closer together. There is a need for scientists to develop a more general concept of risk which includes the public perception as well as the scientific one (Hohenemser et al., 1983). Techniques to reduce intuitive judgment and increase analytical cognition in technological matters should reduce scientific dispute and reduce the public's doubt and confusion over policies concerning the development of nuclear power and waste disposal (Hammond et al., 1984).

## 8. SUMMARY

This section presents a brief summary of some of the main points in the text.

(1) In general, the North American public has limited scientific knowledge of nuclear power technology.

(2) The level of public understanding of health and environmental risks is low.

(3) The public has a fairly good perception of the relative order of probabilities of risk events, but tends, in general, to overestimate small probabilities and underestimate large ones, by factors of 10-1000.

(4) Risk perceptions of the public are influenced more by the anticipated or feared consequences and less by their probability, in contrast to professional studies which focus largely on probabilities.

(5) In estimating probabilities, people are grossly influenced by the manner in which they are asked their opinion and they are prone to manipulation, whether deliberate or inadvertant.

(6) The public perception of risk associated with nuclear power production is wide in scope and ranges over the entire nuclear fuel cycle. There is a concern about radiation, cancer, and mutations, whether resulting from reactor accidents, transportation accidents, uranium mining, radioactive waste, terrorism, or sabotage, although all aspects are not accorded the same weight.

(7) People generally believe that risks are increasing and that, in particular, risk from energy sources is greater now than before.

(8) The public appears to be aware that risks are traded off against benefits, but generally sees the distribution of risks and benefits amongst individuals as less than fair.

(9) The mass media, in order to capture the broadest possible audience, feature the sensational aspects of events rather than basic information. Although they are the primary source of knowledge of the technological base of modern society, the mass media often give an unbalanced view. Mass media tend to exaggerate people's intuitive biases.

(10) There is a strong correlation between the number of newspaper reports of various types of events and people's judgments of the probabilities of such events. Fictional accounts of nuclear power risk, whether in books or movies, are designed for maximum emotional impact and indeed have much greater impact than information.

(11) Expert professionals are apparently as prone to misapplication of judgment as are lay persons, from whom they differ mainly in the amount of information available, rather than in the skill in processing the information.

(12) Some studies show that the variable (deaths per unit energy produced) most frequently chosen by scientists to represent risk may not be a strong factor in the judgment of the public.

(13) The social costs attributable to the public perception of risk associated with nuclear power production should be considered along with direct economic costs.

## 9. CONCLUDING OBSERVATIONS

(1) The general public has little knowledge of the AECB's identity and function. It is unaware, in general, of the extent of the measures taken to control the risks associated with the production of nuclear power.

(2) Many people are concerned that the use of nuclear power, and particularly its export, could lead to the widespread proliferation of nuclear weapons. At the same time few are aware of the international "safeguards" that are in place to detect the diversion of nuclear material from power stations to military use, nor is much known about the important role that Canada plays in this "safeguards" process.

(3) Public debate is an important element in making people aware of the technological aspects and safety of nuclear power production. The quality of this debate could be enhanced in the long run by active promotion of education in this area in cooperation with the provincial governments. More immediate benefits could be realized by promoting closer contacts between technically informed individuals and the press, teachers and special interest groups.

(4) Although the assessment of risk is important in determining the safety of nuclear power plants, the concept of risk as a mathematical expectation of loss fails to capture much of the meaning of "risk" to those who are exposed. It is therefore necessary to promote and support a dialogue between those who do risk analysis and those who study the way in which risk is perceived by the public.

(5) The skills for doing risk assessment of complex technical systems are not widely available. The public's anxiety over the risks of nuclear power technology might be substantially relieved if institutions considered as independent could develop the capacity and provide relevant Canadian data for risk analysis. Active research support from the AECB to universities and private groups could be one way to accomplish this.

(6) Increased public support for the nuclear program may well depend on the success of the current transition from confidentiality to an open process of information exchange between industry, government and the public.

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